

STATISTICS 402 - Assignment 5

Solution

1. A psychologist does a study involving memory. One theory regarding memory states that verbal material is remembered as a function of the degree to which it is processed when it is initially presented. To test this theory a study is run by placing older literate adults into five learning groups. The Counting group reads through a list of words and counts the number of letters in each word. The Rhyming group reads a list of words and thinks of words that rhyme with each word on the list. The Adjective group reads a list of words and thinks of adjectives that modify the words, one adjective for each word. The Imagery group reads a list of words and forms a vivid image for each word. None of these four groups is told that they will later have to recall the words. Subjects in a fifth group, the Intentional group, are asked to memorize a list of words for later recall. After subjects read through a list of words three times, they are asked to write down all the words they can remember. The number of words correctly recalled is noted for each subject.

a) Why is this study an experiment and not an observational study?

This study is an experiment because the study subjects are placed into the learning groups. The factor of interest, learning group, is manipulated by the experimenter.

b) Identify the response, conditions and experimental units.

Response: Number of word correctly recalled.

Conditions: Five learning groups – Counting, Rhyming, Adjective, Imagery and Intentional.

Experimental units: Older literate adults.

c) Give an example of two outside variables that should be controlled in this experiment. Explain briefly how each can be controlled.

The list of words should be the same for all study subjects.

The length of time given to read through the list should be the same for all study subjects.

The length of time given to recall words should be the same for all study subjects.

d) If the experimenter wishes to detect a difference in mean number of words correctly remembered as small as 1 standard deviation with Alpha=0.05 and Beta=0.05, how many study subjects are needed?

39 study subjects for each learning group, or a total of 195 study subjects are needed.

e) The experimenter is able to recruit 50 study subjects. Give two combinations of Alpha, Beta and $\frac{\Delta}{\sigma}$ that correspond to this number of volunteers. Briefly explain the trade-off between your two choices.

1. Alpha = 0.05, Beta = 0.50, $\frac{\Delta}{\sigma} = 1.2$

2. Alpha = 0.01, Beta = 0.50, $\frac{\Delta}{\sigma} = 1.6$

3. Alpha = 0.01, Beta = 0.20, $\frac{\Delta}{\sigma} = 2.0$

4. Alpha = 0.01, Beta = 0.05, $\frac{\Delta}{\sigma} = 2.5$

The tradeoff between 1 and 2 is that you lower your chance of saying a difference exists when none does but raise the size of the detectable difference.

The tradeoff between 2, 3 and 4 is that you lower your chance of missing a difference that is really there but raise the size of the detectable difference.

- f) Describe in detail how you would randomly assign the study subjects to the five groups so that there are an equal number of volunteers in each group. Once you have described what you will do, actually do the randomization. Include your randomized assignment of the 50 study subjects to the 5 groups.

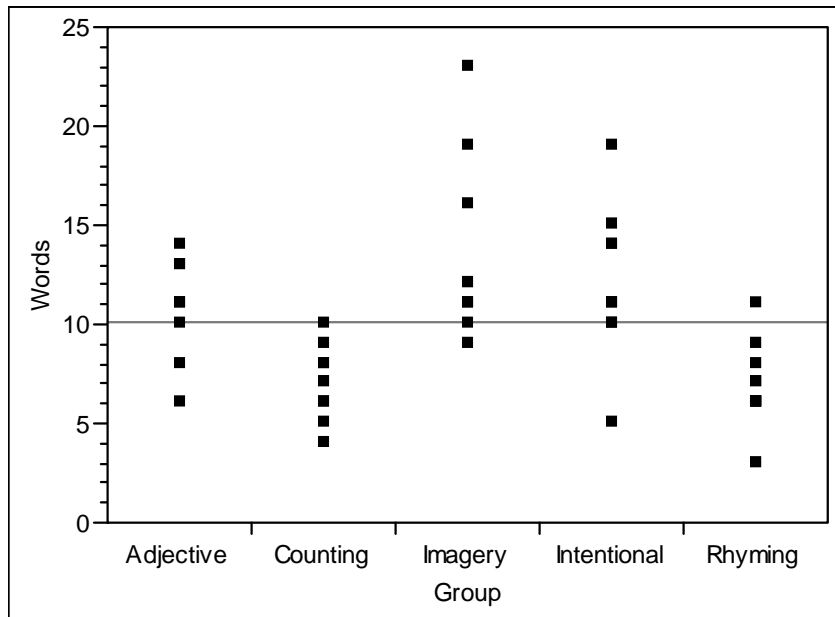
I would assign each individual a unique number from 1 to 50. I would then use JMP to randomly shuffle the numbers from 1 to 50. The first 10 numbers in the shuffled column will be assigned to the Counting group. The second 10 numbers in the shuffled column will be assigned to the Rhyming group. The third 10 numbers will be assigned to the Adjective group. The fourth 10 numbers will be assigned to the Imagery group. The last 10 numbers will be assigned to the Intentional group.

Counting	Rhyming	Adjective	Imagery	Intentional
21	11	14	31	20
9	17	40	28	42
38	48	24	32	35
29	41	3	5	22
37	27	23	8	25
33	10	19	13	36
2	34	16	30	1
43	12	39	4	6
49	47	44	26	18
45	7	15	46	50

2. A completely randomized experiment, as described in problem 1, is run with the following results.

	Counting	Rhyming	Adjective	Imagery	Intentional
	9	7	11	12	10
	8	9	13	11	19
	6	6	8	16	14
	8	6	6	11	5
	10	6	14	9	10
	4	11	11	23	11
	6	6	13	12	14
	5	3	13	10	15
	7	8	10	19	11
	7	7	11	11	11
Mean, \bar{y}	7.0	6.9	11.0	13.4	12.0
Variance, s^2	1.826	2.132	2.494	4.502	3.742

- a) Plot the data. If you use a computer program to plot the data, cut and paste the output on your answer sheet. Based on the plot what can you say about the effectiveness of the various learning methods? What can you say about the consistency of the learning methods?



It appears that the Imagery group remembers the most words, followed closely by the Intentional group and then the Adjective group. Both Counting and Rhyming groups tend to have the fewest number of words recalled.

All groups show variation (inconsistency). The Counting group appears to be the most consistent (least variable). The Imagery and Intentional groups appear to exhibit the most variation. However, the differences in variation are not that pronounced.

- b) Estimate the effect of each of the learning methods.

Group	Group Sample Mean	Estimated Effect
Adjective	11.0	+0.94
Counting	7.0	-3.06
Imagery	13.4	+3.34
Intentional	12.0	+1.94
Rhyming	6.9	-3.16
Overall	10.06	

- c) Construct an analysis of variance table giving sources of variation, degrees of freedom, sums of squares, mean squares, appropriate F statistic and associated P-value. If you use a computer package, you can copy the results from the output onto your answer sheet.

Source	df	Sum of Squares	Mean Square	F	Prob > F
Group	4	351.52	87.88	9.085	< 0.0001
Error	45	435.30	9.673		
C. Total	49	786.82			

- d) Give the value of R^2 and an interpretation of this value.

$R^2 = 0.447$. 44.7% of the variation in the number of words correctly recalled can be explained by the various learning groups.

- e) Are there statistically significant differences amongst the five groups in terms of mean counts of remembered words? Support your answer by referring to the appropriate test of the null hypothesis: $H_0 : \mu_1 = \mu_2 = \mu_3 = \mu_4 = \mu_5$.

The test statistics is $F = 9.085$ with an associated P-value that is less than 0.0001. The small P-value indicates that there are some learning groups with group sample means that are different from others and that those differences are statistically significant.

- f) If there are statistically significant differences, which groups are different? Support your answer with a multiple comparisons method. Be sure to discuss the chance of committing at least one error in the set of pair-wise comparisons of groups.

Because there are 5 groups there are 10 possible pair-wise comparisons. To keep the chance that at least one comparison will result in a Type I error I chose to do Tukey's HSD method. $HSD = 3.952$. Any difference between two group sample means greater than 3.952 is considered statistically significant.

Imagery, Intentional and Adjective groups have means that are not statistically different.

Counting and Rhyming groups have means that are not statistically different.

Imagery, Intentional and Adjective are all statistically different from Counting and Rhyming.

- g) Look at the distribution of residuals. What does this tell you about the conditions necessary for the analysis of variance? Be sure to tell me what you see in the plots and how that relates to the specific conditions.

The plot of residuals versus group shows fairly similar spreads. Imagery and Intentional have slightly larger spreads than the other three groups. However, looking at the sample standard deviations of the groups, no sample standard deviation is three or more times bigger than another.

The distribution of residuals has a histogram that is slightly skewed to the right. The box plot shows an overall mean slightly larger than the median (consistent with a right skew) and the largest residual is a potential outlier. The normal quantile plot has points starting off following the Normal model line, then drifts above and eventually drifts below (again consistent with a right skew).

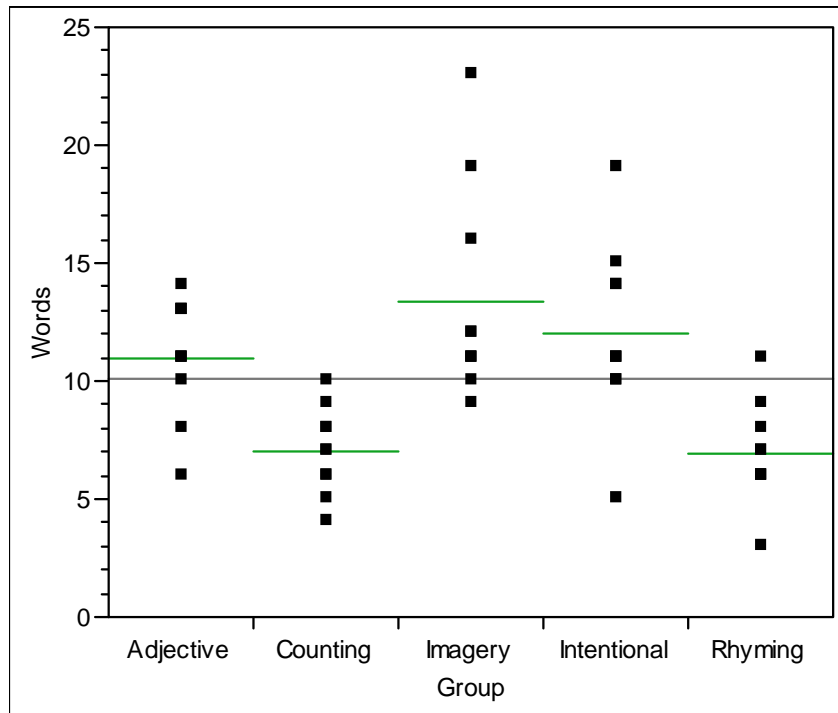
The equal standard deviation condition is not violated. The Normal distribution condition is violated slightly because of the right skew and potential outlier. However, the results of the analysis are not in question.

- h) Write a brief summary (one or two sentences is enough) of the findings of the experiment. In this summary make a recommendation based on your analysis as to what learning method should be used.

The analysis of the data arising from the experiment where older literate adults are randomly assigned to different learning groups indicates that some groups do better than others in recalling words correctly and that some of those differences are statistically significant. Specifically, if one wanted to have older literate adults do better at remembering words correctly then asking them to use adjectives, imagery or telling them to intentionally recall the words will get better results than having them count letters in words or using rhyming.

Note: If you use a computer program to analyze the data, include only the appropriate output to answer each question. It is helpful if the output used to answer a question is specifically referenced.

JMP Output for Memory Experiment



Means and Std Deviations

Level	Number	Mean	Std Dev
Adjective	10	11.0000	2.49444
Counting	10	7.0000	1.82574
Imagery	10	13.4000	4.50185
Intentional	10	12.0000	3.74166
Rhyming	10	6.9000	2.13177

Oneway Anova Summary of Fit

Rsquare	0.44676
Adj Rsquare	0.397584
Root Mean Square Error	3.110198
Mean of Response	10.06
Observations (or Sum Wgts)	50

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Group	4	351.52000	87.8800	9.0848	<.0001
Error	45	435.30000	9.6733		
C. Total	49	786.82000			

Means Comparisons

Comparisons for each pair using Student's t

t Alpha
2.01410 0.05

Abs(Dif)-LSD	Imagery	Intentional	Adjective	Counting	Rhyming
Imagery	-2.8015	-1.4015	-0.4015	3.5985	3.6985
Intentional	-1.4015	-2.8015	-1.8015	2.1985	2.2985
Adjective	-0.4015	-1.8015	-2.8015	1.1985	1.2985
Counting	3.5985	2.1985	1.1985	-2.8015	-2.7015
Rhyming	3.6985	2.2985	1.2985	-2.7015	-2.8015

Positive values show pairs of means that are significantly different.

Level	Mean
Imagery A	13.400000
Intentional A	12.000000
Adjective A	11.000000
Counting B	7.000000
Rhyming B	6.900000

Levels not connected by same letter are significantly different.

Comparisons for all pairs using Tukey-Kramer HSD

q* Alpha
2.84145 0.05

Abs(Dif)-LSD	Imagery	Intentional	Adjective	Counting	Rhyming
Imagery	-3.9522	-2.5522	-1.5522	2.4478	2.5478
Intentional	-2.5522	-3.9522	-2.9522	1.0478	1.1478
Adjective	-1.5522	-2.9522	-3.9522	0.0478	0.1478
Counting	2.4478	1.0478	0.0478	-3.9522	-3.8522
Rhyming	2.5478	1.1478	0.1478	-3.8522	-3.9522

Positive values show pairs of means that are significantly different.

Level	Mean
Imagery A	13.400000
Intentional A	12.000000
Adjective A	11.000000
Counting B	7.000000
Rhyming B	6.900000

Levels not connected by same letter are significantly different.

JMP Output for Analysis of Residuals

